REMARKS

This amendment is responsive to the Office Action mailed May 16, 2007. Reconsideration and allowance of claims 1-10, 12-14, and 17-21 are requested.

The objections to the drawings are addressed

A replacement sheet 1/11 is provided which replaces the fuzzy magnetic resonance scanner (10) of Fig. 1 with a line drawing. Applicants respectfully request that the replacement sheet be entered, and the objections to the drawings be withdrawn in view of this replacement sheet.

Status of the Claims

Claims 1-13, 15-19, and 21 stand rejected under 35 U.S.C. § 102(e) as allegedly anticipated by Zhu et al., U.S. Pat. No. 7,009,396 (hereinafter "Zhu").

Claims 1 and 17-20 stand rejected under 35 U.S.C. § 102(b) as allegedly anticipated by King, U.S. Pat. No. 6,242,916 (hereinafter "King").

Claim 14 stands rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Zhu in view of Wang, U.S. Pat. No. 6,650,925.

The Amendments

The present application relates to achieving reduced readout time without degrading image resolution or introducing undesired aliasing, by reducing sampling in the readout direction or in both readout and phase encode directions. In some embodiments the readout is undersampled producing a reduced FOV and aliasing in the readout direction in the measurement images, and the combining of the data from multiple coils restores the desired FOV and removes of the aliasing (e.g., Figs. 4-6). In some embodiments, the readout is not undersampled, but rather a shortened read magnetic field gradient profile is used producing sampling of the center of k-space (i.e., maps to low frequency readout values of a k-space) but not sampling of higher frequency k-values, and the combining of the data from multiple coils restores the resolution (e.g., Figs. 9-11). In some embodiments, the foregoing are combined with SENSE in the phase encode direction (e.g., Fig. 7-8 and 11).

Claim 1 has been amended to incorporate subject matter of canceled claim 11, namely that the sampling means undersamples the receive coils at a reduced sampling rate in the readout direction such that the intermediate reconstructed images include aliasing in at least the readout direction, the combining means removing said aliasing during the combining.

Claim 9 has been placed into independent form, and calls for acquiring samples in the readout direction that map to low frequency readout values of a k-space and not to higher frequency readout values of the k-space.

Claim 17 has been amended to include subject matter of the second element of the Markush group of claim 21, namely sampling at a reduced sampling rate (i.e., undersampling) such that the combining restores FOV in the readout direction.

Claim 21 has been placed into independent form retaining only the first element of the Markush group, namely sampling over a shortened read magnetic field gradient profile such that the combining restores resolution in the readout direction, and to further call for sampling in central region of k-space in the readout direction while completely omitting sampling of high readout k-values in the readout direction. The latter amendment is supported at least at page 12 lines 25-26 and Figs. 10 and 11 of the original specification.

The claims distinguish patentably over the references

Claim 1 includes subject matter of canceled claim 11 that was rejected as allegedly anticipated by Zhu.

Zhu relates to parallel imaging of a subject in continuous motion, e.g. for head-to-toe imaging of a continuously moving subject. By using multiple receive coils each imaging a different spatial area (i.e., different sub-images), the sub-images of several different FOV's can be acquired simultaneously and then knitted together to form a larger image. By making these FOV overlapping, the accuracy of such knitting is enhanced (e.g., Zhu Fig. 3; col. 6 lines 27-33) and the discontinuity artifacts associated with sub-image edge boundaries, i.e. "stitching artifacts", are minimized (Zhu col. 7 lines 1-7). Thus, the approach of Zhu does combine sub-images to generate a larger FOV than that provided by any individual sub-image alone.

However, Zhu does not disclose or fairly contemplate a sampling means that undersamples the receive coils at a reduced sampling rate in the readout direction such that the intermediate reconstructed images include aliasing in at least the readout direction, the combining means removing said aliasing during the combining. Rather, each sub-image of Zhu is fully sampled in the readout direction, and is reconstructed to provide an unaliased sub-image in the readout direction. These unaliased sub-images are knitted together to form the larger FOV image. At most, Zhu employs conventional SENSE in the phase encoding direction, not in the readout direction, and teaches undersampling in the phase encode direction, but not in the readout direction. See Zhu col. 7 line 60-col. 8 line 2 ("reducing phase encoding steps"); col 8 lines 37-42 ("Reduction of k-space sampling is in effect in the present case, and leads to aliasing along the phase encoding direction(s) in each of the regional images. Applying SENSE or other parallel imaging reconstruction on the regional images that are produced in parallel generates a regional image free of aliasing.")

King cannot remedy these deficiencies of Zhu. King discloses parallel imaging using two coils. Initially, it should be noted that the two receive channels do not include coil 152A, which is described as a transmit-only coil (see col. 4 lines 40 ff), but elsewhere such as at col. 5 lines 3-6 King does disclose using two receiver channels with coil 152B being an illustrative receive coil. Indeed, King discloses sampling using more than two receive channels at col. 7 lines 19-20.

King discloses a combination of two techniques, namely Homodyne imaging and SENSE. In the disclosed Homodyne imaging (the lefthand path of Fig. 3), only the negative half of k-space is acquired, e.g. samples [-64,+8] (col. 2 lines 1-9; col. 6 line 64) and the missing positive half of k-space is filled in based on an assumption of Hermitian conjugate symmetry of k-space to generate a complete image data set for each coil (col. 2 lines 10-35; col. 5 lines 44-64).

King recognizes that Homodyne processing may introduce phase errors (col. 5 lines 63-65). These are compensated by processing in the righthand path of Fig. 3 which selects central k-space data (e.g., region [-8,8], see col. 6 line 60-67) that is Fourier transformed in the phase-encoding direction and processed by SENSE to generate an image I_L that is used to correct any phase errors resulting from the Homodyne processing (col. 7 lines 1-15).

King also proposes to perform SENSE, optionally including SENSE in the readout direction, as part of the lefthand (Homodyne) image processing path of Fig. 3. See col. 5 line 66-col. 6 line 59. However, there is no disclosure in King to undersample in the readout direction or to acquire data in the readout direction at a reduced sampling rate. King discloses acquiring partial data sets consisting of the negative half of k-space (col. 5 lines 33-43), and filling in the missing half by Homodyne processing. SENSE is then proposed by King to be performed after the positive half of k-space has been filled by the Homodyne processing, on what are described by King as complete image data sets (col. 5 lines 60-65). SENSE is generally known as a technique applied to undersampled data sets, not complete data sets. It is not clear why or how King would go about applying SENSE in the readout direction to combine these already-complete image data sets. The only (allegedly) worked out example provided by King relates to conventional SENSE applied in the phase encoding direction (King col. 6 lines 5-54).

For at least the foregoing reasons, it is respectfully submitted that claim 1 is in condition for allowance. Accordingly, Applicants respectfully request allowance of claim 1 and of claims 2-7, 12, and 13 that depend therefrom.

Claim 9 calls for, among other elements, a sampler acquiring samples in the readout direction that map to low frequency readout values of a k-space and not to higher frequency readout values of the k-space, a reconstruction processor configured to reconstruct intermediate reconstructed images having a measurement spatial resolution in the readout direction, and a means for combining the intermediate reconstructed images based on coil sensitivity factors to produce a final reconstructed image having a final spatial resolution in the readout direction that is increased over the measurement spatial resolution in the readout direction.

Claim 9 stands rejected based on Zhu. However, Zhu does not disclose or fairly suggest acquiring samples in the readout direction that map to low frequency readout values of a k-space and not to higher frequency readout values of the k-space, much less combining based on coil sensitivity factors to produce a final reconstructed image having a final spatial resolution in the readout direction that is increased over the measurement spatial resolution in the readout direction.

Regarding the citation to Zhu col. 6 lines 28-35 at page 6 of the Office Action, it is respectfully submitted that the use of different frequencies or phases for the different receivers may result in a shifting of the "real-space" FOV, even if the operations are performed wholly in k-space. In any event, the cited portion of Zhu at most discloses acquiring a central portion of k-space, but does not disclose not acquiring higher frequency readout values of the k-space.

King cannot remedy these deficiencies of Zhu. King discloses acquiring the negative half of k-space and filling in the positive half by Homodyne processing. Thus, King does not disclose or fairly suggest not acquiring higher frequency readout values of the k-space, but rather teaches acquiring the entire negative k-space including the higher frequency readout values. The entire negative k-space portion is then used in the Homodyne processing to generate a complete image data set.

For at least the foregoing reasons, it is respectfully submitted that claim 9 is in condition for allowance. Accordingly, Applicants respectfully request allowance of claim 9 and of claims 8, 10, and 14 that depend therefrom.

Claim 17 calls for sampling magnetic resonance signals in the readout direction using a plurality of receive coils at a measurement sampling rate undersampled in the readout direction, reconstructing the magnetic resonance samples acquired from each coil into a corresponding intermediate reconstructed image having a measurement field of view in the readout direction and having aliasing in the readout direction due to the undersampling in the readout direction, and combining the intermediate reconstructed images based on coil sensitivity factors to produce a final reconstructed image having a final field of view in the readout direction that is increased over the measurement field of view in the readout direction, the combining restoring field of view in the readout direction and removing the aliasing in the readout direction.

Zhu does not disclose or fairly suggest either undersampling in the readout direction or combining the intermediate reconstructed images based on coil sensitivity factors to produce a final reconstructed image having a final field of view in the readout direction that is increased over the measurement field of view in the readout direction, the combining restoring field of view in the readout direction and removing the aliasing in the readout direction. At most, Zhu discloses SENSE performed in the phase encoding direction, not the readout direction.

King does not disclose sampling magnetic resonance signals in the readout direction using a plurality of receive coils at a measurement sampling rate undersampled in the readout direction. At most, King discloses acquiring only the negative half of k-space in the readout direction, but does not disclose or fairly suggest undersampling in the readout direction.

For at least the foregoing reasons, it is respectfully submitted that claim 17 is in condition for allowance. Accordingly, Applicants respectfully request allowance of claim 17 and of claims 18-20 that depend therefrom.

Claim 21 calls for sampling the magnetic resonance signals in the readout direction using a plurality of receive coils to acquire magnetic resonance samples from each coil in the central region of k-space in the readout direction while completely omitting sampling of high readout k-values in the readout direction, reconstructing intermediate reconstructed images having a measurement spatial resolution in the readout direction, and combining the intermediate reconstructed images based on coil sensitivity factors to produce a final reconstructed image having a final spatial resolution in the readout direction that is increased over the measurement spatial resolution in the readout direction and wherein the sampling is performed over a shortened read magnetic field gradient profile such that the combining restores resolution in the readout direction

Neither Zhu nor King disclose or fairly suggest acquiring magnetic resonance samples from each coil in the central region of k-space in the readout direction while completely omitting sampling of high readout k-values in the readout direction. Zhu collects complete data sets in the readout direction, and at most may employ undersampling coupled with SENSE in the phase encoding direction. King discloses collecting the entire negative half of k-space in the readout direction, including sampling of high readout k-values in the readout direction.

For at least the foregoing reasons, it is respectfully submitted that claim 21 is in condition for allowance. Accordingly, Applicants respectfully request allowance of claim 21.

CONCLUSION

For the reasons set forth above, it is submitted that claims 1-10, 12-14, and 17-21 distinguish patentably over the references of record and meet all statutory requirements. An early allowance of all claims is requested.

In the event that personal contact is deemed advantageous to the disposition of this case, the Examiner is requested to telephone the undersigned at (216) 861-5582.

Respectfully submitted,

FAY SHARPE LLP

Robert M. Sieg

Thomas E. Kocovsky, Jr.
Reg. No. 28,383
Robert M. Sieg
Reg. No. 54,446
1100 Superior Avenue, 7th Floor
Cleveland, OH 44114-2579
(216) 861-5582